- "Both Orbcomm and GE Starsys continue to assert their abilities to share their proposed service link frequencies with future systems."[16]

- "... we may find it necessary to relocate a licensee's operations within the spectrum in an effort to coordinate future systems."[17]

- "Applicants for authority to establish NVNG MSS systems are encouraged to coordinate their proposed frequency usage with existing permittees and licensees .... All affected applicants, permittees, and licensees shall, at the direction of the Commission, cooperate fully and make every reasonable effort to resolve technical problems and conflicts ...."[18]

12 December 1993

Addition to LEOTELCOM-2 AP3 received by BR, published as RES/46/C/50 ADD-1, states that system will comply with RR608A. No impact on 137 - 138 MHz band.

25 April 1994

GE Starsys amends its FCC application stating:

- "... the spread-spectrum pfd at the ground in the 137 - 138 MHz band is reduced from -147.76 dB(W/m^2/4 kHz) to -156 dB(W/m^2/4 kHz) ....[19]"

- "The sharing agreement allows all three applicants to operate successfully while leaving room for additional applicants at a later date."[20]

- "GE Starsys will share this band [137 - 138 MHz] with Orbcomm and existing METSAT services."[21]

- "Power flux density calculations in the 137 - 138 MHz band ... - 156.2 dB(W/m^2/4 kHz)"[22]

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16 Footnote 38.

17 Footnote 39.

18 47 CFR 25.142 (b) (3).

19 Page 11.

20 Page A-21, 5.1.

21 Page A-21, 5.1.3.

22 Page A-23, Table A-5.

APPENDIX F

APPENDIX F

ITU DOCUMENT 8D/TEMP/133-E

INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION
STUDY GROUPS

Document 8D/TEMP/133-E
5 November 1996
Original: English

Source: Documents 8D/135 and 150

Sub-Drafting Group 8D3A-4

WORKING DOCUMENT TOWARDS DRAFT NEW RECOMMENDATIONS

METHODS FOR MODELLING FREQUENCY SHARING BETWEEN STATIONS IN THE LAND MOBILE SERVICE BELOW 1 GHz AND NON-GEOSTATIONARY SATELLITE ORBIT (NON-GSO) MOBILE EARTH STATIONS

Attachment 1 - Preliminary draft new Recommendation and Attachment 2 - working document for draft new Recommendation are provided for study and evaluation until the next Working Party 8D meeting.

Attachment 1, "Method for the Statistical Modelling of Frequency Sharing Between Stations in the Land Mobile Service Below 1 GHz and FDMA Non-Geostationary Satellite Orbit (Non-GSO) Mobile Earth Stations", provides a method for using simulation techniques to statistically estimate the probabilities of interference, the mean times between interference events, and the lower bound number of land mobile stations that would allow non-GSO mobile earth stations to find a sufficient number of available Earth-to-space channels to operate in a frequency sharing environment with stations in the land mobile service. The propagation model used is the same as used in ITU-R Recommendation M.1039.

Attachment 2, "A Methodology for Calculating Interference Probability from Non-GSO MSS Mobile Earth Station to Land Mobile Station Operating Below 1 GHz", provides an analytic methodology for calculating interference probability from non-GSO MSS mobile earth stations to land mobile stations, under the circumstances as follows: a) interference from MES stations to base station of the existing LMS station with higher antenna, b) interference not only to LMS stations but also to radio-relay stations of LMS, c) using a propagation model derived from ITU-R Recommendation PN.370-7.

Participants in Working Party 8D are requested to closely examine the two attachments and to consider and evaluate the methodologies, the assumptions, and the technical parameters used to represent the MSS and the LMS systems.

This document is also being referred to Working Party 8A for examination.

Source: Document 8D/150

ATTACHMENT 1

PRELIMINARY DRAFT NEW RECOMMENDATION

METHOD FOR THE STATISTICAL MODELLING OF FREQUENCY SHARING BETWEEN STATIONS IN THE LAND MOBILE SERVICE BELOW 1 GHz AND FDMA NON-GEOSTATIONARY SATELLITE ORBIT(NON-GSO) MOBILE EARTH STATIONS

(Questions ITU-R 83-3/8, 84-3/8, and 201/8)

Summary

This Recommendation provides a method for using simulation techniques to statistically estimate the probabilities of interference, the mean times between interference events, and the lower bound number of land mobile stations that would allow non-GSO mobile earth stations to find a sufficient number of available Earth-to-space channels to operate in a frequency sharing environment with stations in the land mobile service. The propagation model used herein is the same as used in ITU-R Recommendation M.1039.

The ITU Radiocommunication Assembly,

considering

a) that Resolution 214 (WRC-95) invited the ITU-R to study and develop Recommendations on the technical and operational issues relating to sharing between services having allocations and the non-GSO MSS below 1 GHz in the bands proposed to WRC-95 and in other frequency bands;

b) that the spectrum already allocated or being considered for allocation by world radio conferences for low-Earth orbit (LEO) mobile-satellite services (MSS) below 1 GHz, if shared with land mobile services, must provide adequate protection from harmful interference;

c) that LEO MSS can provide beneficial radio-based services to a large community of travellers;

d) that the use of LEO enables practical use of frequencies below 1 GHz by space stations;

e) that some coordination and channelization techniques used in fixed and mobile radio systems in bands below 1 GHz can lead to low Erlang loading on individual channels;

f) that dynamic channel assignment techniques are technically feasible and may provide a means of spectrum sharing between land mobile services and low power, low duty cycle mobile-satellite services;

g) that the users would operate throughout large geographic areas;

h) that the transmission of the MES are short bursts;

j) that the signal characteristics in the MSS below 1 GHz may allow co-channel sharing with mobile and fixed service networks,

recommends

1 that the statistical modelling methods described in Annex 1 be used to evaluate frequency sharing between stations in the land mobile services below 1 GHz and FDMA non-geostationary satellite orbit mobile earth stations in the same frequency band.

ANNEX 1

Statistical Modelling of Frequency Sharing Between Stations in the Mobile Service Below 1 GHz and Mobile-Satellite Service (MSS) Earth Station Transmitters

1 Introduction

This Annex describes a method to be used to determine if mobile-satellite service (MSS) earth station transmitters can share spectrum with land mobile services. Land mobile services in the bands below 1 GHz are typically characterized by voice and data carriers that may be analog or digitally modulated and are assigned on a periodic channel grid. Channel spacings used include 6.25 kHz, 12.5 kHz, and 25 kHz. The MSS systems would perform Earth-to-space transmissions using short-term bursts on an intermittent basis with a low duty cycle. ITU-R Recommendation M.1039 notes that burst lengths might be up to 500 ms and that the time duration of 1% in 1 - 15 minutes has been suggested. MSS systems below 1 GHz may use a dynamic channel assignment algorithm which allows the space station to identify those channels not occupied by the mobile stations which are sharing the spectrum. A receiver in the satellite monitors the entire shared frequency band and determines which segments of the spectrum are currently being used by the LMS system or for non-GSO MSS uplinks. With the band-scanning receiver on board the satellite, there is very little chance for interference from mobile earth stations to land mobile system receivers. There are, however, several circumstances where the dynamic channel assignment technique would fail to identify an active LMS channel: 1) LMS power level below the detection threshold of the satellite band-scanning receiver, 2) blockage on the path from the LMS transmitter to the satellite so the received signal level is not high enough to be detected, 3) a LMS transmitter begins operation on a channel during a MSS transmission on what had previously been measured as a clear channel. The methodology in Section 2 provides calculation of the probability of interference to a LMS receiver from MES transmissions within a single MSS system, given that the dynamic channel assignment technique has not identified an active LMS channel for the reasons given above, or for any other reason.

The other possibility for mutual interference is LMS transmissions interfering into the MSS space station receiver. With the MSS band scanning receiver identifying clear Earth-to-space channels for MES use, this type of interference can be avoided. Section 3 provides a statistical method that can be used to provide assurance of finding a sufficient number of clear channels to carry the MSS earth-to-space transmissions. However, there remains the possibility of an LMS transmitter beginning operation on a previously clear channel during the short interval of a MES transmission on that channel , and thereby potentially causing interference into the space station receiver.

2 Statistical modelling of interference from non-geostationary satellite orbit, mobile-satellite service, mobile earth stations (NGSO MSS MESs) into land mobile stations

The following statistical model determines the probability of interference without dynamic channel assignment being used. This worst case assumption provides an upper bound on the actual probability of interference for a single non-GSO MSS network with dynamic channel assignment.

The input parameters are:

a) Land Mobile Channelization Plan (25, 12.5 or 6.25 kHz) - Used to determine land mobile link centre frequency and receiver IF bandwidth as shown in Table 2-1.

TABLE 2-1

Land Mobile Channelization Plans

Channelization Plan	IF Bandwidth
25 kHz	16 kHz
12.5 kHz	8 kHz
6.25 kHz	4 kHz

b) MES Uplink Data Rate (9.6, 4.8, or 2.4 kbps) - Used to determine the MES transmit spectrum as shown in Figure 2-1 and transmit power as shown Table 2-2.

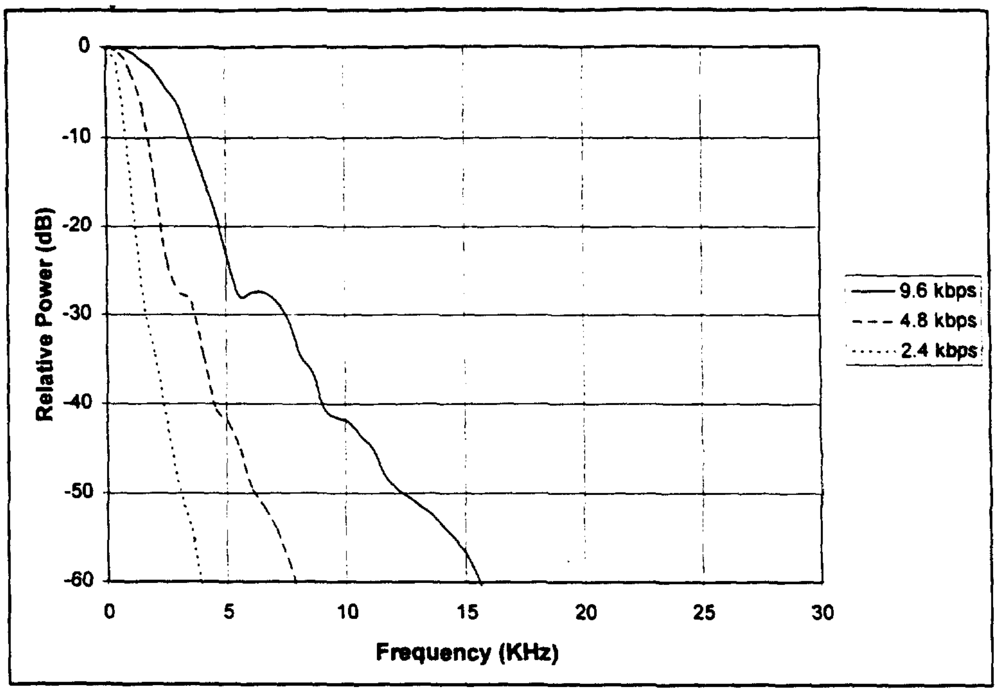

FIGURE 2-1

MES Transmit Signal Masks

TABLE 2-2

MES Transmit Powers

Data Rate	Transmit Power*
9.6 kbps	7 W
4.8 kbps	3.5 W
2.4 kbps	1.75 W
*Transmit Power that provides -140 dBW at edge of coverage.	

c) MES Distribution (Uniform or Clustered) - The uniform distribution models the MESs as uniformly distributed over the land area within the MSS satellite uplink beam. The clustered distribution places the MESs within the satellite beam with probability density roughly proportional to population density.

d) MES Channel Selection (Random or Interstitial) - For the random selection algorithm, the MSS uplink channels are selected randomly on a 2.5 kHz grid across the entire frequency band to be shared (1 MHz, for example). For the interstitial algorithm, the MSS uplink channels are restricted to interstitial locations between the land mobile channels.

For a given set of input parameters, a sufficient number of ½-second trials are performed to insure that the computed probability of interference is reliable. For each ½- second trial the following steps are performed:

1) A land mobile transmitter location is randomly selected as the centre of one of the 20 most populous cities within the MSS satellite uplink beam.

2) The land mobile receiver location is randomly selected using a circular mass distribution from 0 km to edge of coverage from the transmitter location.

3) A land mobile link centre frequency, CF_{LM}, is randomly selected in a 1 MHz bandwidth based on the input land mobile channelization plan.

4) The land mobile receiver IF bandwidth, B_{IF}, is determined from the input channelization plan.

5) The distance between the land mobile transmitter and the land mobile receiver, d_{LM}, is computed.

6) One hundred and twenty-eight active MESs are randomly selected each ½-second within the satellite beam using the input distribution, either uniform or clustered. This corresponds to over 22 million MES transmissions per day from the beam coverage area, which assumes that the NGSO MSS system is operating at 100% of theoretical capacity. This is another worst case assumption.

7) The distances, $d_{MES\text{-}LM}$, from each of the MESs to the land mobile receiver are computed.

8) Centre frequencies, CF_{MES}, are randomly selected in a 1 MHz band for each of the MESs using the input selected method, uniform or interstitial.

9) The MES effective isotropic radiated power spectrum, $EIRP_0(f)$, is determined based on the input data rate.

10) The carrier-to-noise-plus-interference ratio is computed as follows:

$$C/(N+I) = \frac{\dfrac{10^{3.204}W}{d_{LM}^4}}{10^{-15.07}W + \displaystyle\int_{CF_{LM}-\frac{B_{IF}}{2}}^{CF_{LM}+\frac{B_{IF}}{2}} \sum_{MESs} \frac{10^{2.815}\cdot EIRP_0(CF_{MES}-f)}{d_{MES-LM}^4}\,df}$$

This equation uses the propagation model in ITU-R Recommendation M.1039, with antenna heights of 1.5 m for both the LMS transmitter and receiver and for the MES transmitter.

11) If C/(N+I) is less then 10.7 dB then the trial is deemed to have resulted in interference.

The probability of interference is computed as the ratio of the number of trials resulting in interference divided by the total number of trials. This result is the probability of interference to the LMS receiver if it were to be receiving transmissions continuously.

For cases with low LMS traffic loading, the probability of interference is reduced by the Erlang factor for the channel.

3 Modelling of interference from land mobile stations into NGSO MSS satellites

Narrow-band non-GSO MSS networks will use dynamic channel assignment techniques to avoid channels being actively used by land mobile stations. Thus as long as the dynamic channel assignment system correctly identifies all active land mobile channels, there is no possibility of interference from land mobile stations into non-GSO MSS satellites. This model examines if there would be a sufficient number of unused, clear channels available to support non-GSO MSS operations.

The simulation determines the number of land mobile stations in the satellite beam that can operate in the shared spectrum and still provide an average of at least 6 channels per satellite for the NGSO MSS uplinks. This worst case assumption provides a lower bound on the number of land mobile stations that can operate in the shared spectrum while still allowing the NGSO MSS network to operate at 36% of theoretical capacity.

The input parameters are:

a) Land Mobile Channelization Plan (25, 12.5 or 6.25 kHz) - Used to determine land mobile station centre frequency grid, and land mobile transmit spectrum as shown in Figure 3-1.

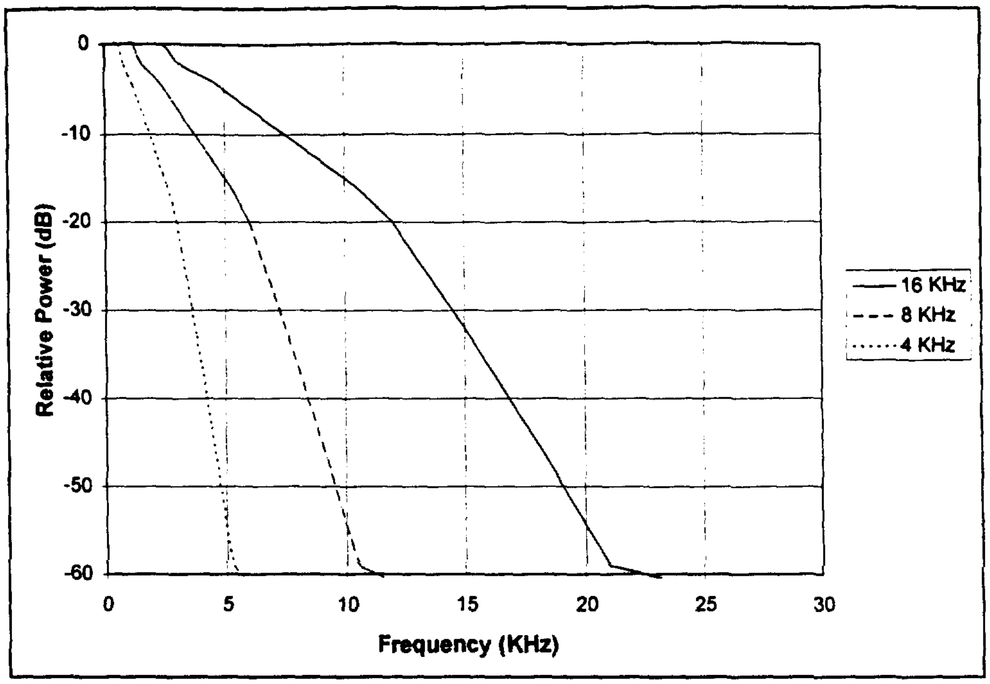

FIGURE 3-1

Land Mobile Station Transmit Signal Masks

b) MES Uplink Data Rate (9.6, 4.8, or 2.4 kbps) - Used to determine the NGSO MSS uplink centre frequency grid as shown in Table 3-1.

TABLE 3-1

MES Uplink Channel Bandwidths

Data Rate	Channel Bandwidth
9.6 kbps	15 kHz
4.8 kbps	10 kHz
2.4 kbps	5 kHz

c) Amount of shared spectrum (1 MHz or 5 MHz).

d) Land mobile station average activity factor (0.01, 0.003, 0.001, or 0.0003 Erlang).

For each set of input parameters, the following steps are performed:

1) The initial number of land mobile stations is set to 1 000.

2) The land mobile stations are randomly distributed across the area covered by the satellite uplink beam.

3) The land mobile transmitter effective isotropic radiated power spectrum, $EIRP_0(f)$ is determined based on the input land mobile channelization plan.

4) The NGSO MSS satellite system uplink channel bandwidth, BW, is determined based on the input MES uplink data rate.

5) For each trial, the NGSO MSS satellite constellation is randomly rotated in time, a sufficient number of trials are performed to insure that the computed number of land mobile stations is reliable. The following steps are performed:

   a) For each land mobile station, a transmit centre frequency, CF_{LMS}, is randomly selected in the input amount of shared spectrum, 1 MHz or 5 MHz, based on the input land mobile channelization plan.

   b) For each land mobile station and for each NGSO MSS satellite the Doppler frequency shift, $\Delta f_{Doppler}$, is computed taking account of the relative velocities of the transmit and receive equipments.

   c) For each NGSO MSS satellite and for each NGSO MSS uplink channel centre frequency, CF_{CH}, in the input amount of shared spectrum, the interference-to-noise ratio is computed as follows:

$$(I/N)_{CH} = 10^{6.25} \cdot \int_{CF_{CH}-\frac{BW}{2}}^{CF_{CH}+\frac{BW}{2}} \sum_{LMSs} EIRP_0(CF_{LMS} + \Delta f_{Doppler} - f)df$$

This equation uses the propagation model used in ITU-R Recommendation M.1039, for antenna heights of 1.5 m at both the LMS transmitter and receiver and the MES transmitter.

   d) For each NGSO MSS satellite, the number of clear channels is computed as the sum of those with $I/N < 10$ dB.

6) If the minimum of the computed numbers of clear channels is greater than 6, then the number of land mobile stations is increased by 1 000 and the above procedure is repeated starting at step 2.

7) The process is completed when the maximum number of LMS stations that still allows for 6 clear channels is found.

APPENDIX A

(To Annex 1)

Example applications of the statistical models

1 Introduction

This Appendix shows examples of application of the two statistical models contained in this Recommendation.

The example non-GSO MSS network used has the following characteristics: 48 satellites in 8 orbital planes inclined 50 degrees to the equator; each plane contains six equally spaced satellites in 950 km altitude circular orbits; narrow-band frequency division multiplexing for the Earth-to-space transmissions; operation in a store-and-forward mode; transmissions within 500 ms frames containing digital packets; satellite use of a band scanning receiver to implement a dynamic channel activity assignment system (DCAAS) that assigns unused channels to earth stations for uplink transmissions; and uplink data rates of 2.4, 4.8, and 9,6 kbps. It is assumed that the one MSS system is operating at maximum capacity over a specific geographic area, (for this example, 22 million Earth-to space packet transmissions per day over the contiguous United States).

The land mobile stations modelled have the following characteristics: analogue, frequency modulation system (or digitally modulated, binary-FSK system); a vertically polarized antenna having 0 dBi gain towards the satellite; minimum received signal power assumed to be -140 dBW; and channel bandwidths of 6.25, 12.5 and 25.0 kHz with low Erlang loading on individual channels. The technical characteristics used in the model are for certain LMS systems operating in the bands below 1 GHz.

2 Potential interference from non-GSO MSS earth stations into land mobile stations

The distance between the land mobile station and its base station is modelled by a circular mass distribution from 0 to 20 km with 20 km corresponding to threshold received power. Both uniform and clustered distribution of MSS earth stations are considered. A 1 MHz shared frequency band is assumed with both random and interstitial uplink channel selection algorithms considered.

Table A-1 shows the upper bound probability of interference computed by the simulation program for the range of parameters examined. The significance of the raw probabilities may be difficult to interpret, so they have been converted to mean time between interference events as shown in Table A-2. Results in Tables A-1 and A-2 are for the condition that the land mobile station is operating continuously. Table A-3 shows the mean time between interference events for a typical land mobile user with 0.01 Erlangs of traffic.

TABLE A-1

Probability of Interference

Land Mobile Channelization	MES Uplink Data Rate	Uniform Distribution: Random Selection	Uniform Distribution: Interstitial Selection	Clustered Distribution: Random Selection	Clustered Distribution: Interstitial Selection
25 kHz	9.6 kbps	0.00038	0.000055	0.0013	0.00020
	4.8 kbps	0.00025	0.0000058	0.00088	0.000022
	2.4 kbps	0.00016	0.00000093	0.00052	0.0000034
12.5 kHz	9.6 kbps	0.00023	0.00019	0.00075	0.00064
	4.8 kbps	0.00012	0.000020	0.00039	0.000069
	2.4 kbps	0.000067	0.0000024	0.00023	0.0000084
6.25 kHz	9.6 kbps	0.00014	0.00015	0.00049	0.00051
	4.8 kbps	0.000094	0.00011	0.00032	0.00037
	2.4 kbps	0.000066	0.000074	0.00023	0.00026

TABLE A-2

Worst Case (Smallest) Mean Time Between Interference Events

Land Mobile Channelization	MES Uplink Data Rate	Uniform Distribution: Random Selection	Uniform Distribution: Interstitial Selection	Clustered Distribution: Random Selection	Clustered Distribution: Interstitial Selection
25 kHz	9.6 kbps	22 min	*3 hours*	7 min	42 min
	4.8 kbps	34 min	*24 hours*	10 min	*7 hours*
	2.4 kbps	50 min	*150 hours*	16 min	*41 hours*
12.5 kHz	9.6 kbps	36 min	44 min	11 min	13 min
	4.8 kbps	70 min	*7 hours*	22 min	120 min
	2.4 kbps	130 min	*60 hours*	36 min	*17 hours*
6.25 kHz	9.6 kbps	60 min	55 min	17 min	17 min
	4.8 kbps	90 min	75 min	26 min	23 min
	2.4 kbps	130 min	120 min	36 min	32 min

TABLE A-3

Mean Time Between Interference Events For Typical Push-to-Talk User (0.01 Erlang)

		Uniform Distribution		**Clustered Distribution**	
Land Mobile Channelization	**MES Uplink Data Rate**	**Random Selection**	**Interstitial Selection**	**Random Selection**	**Interstitial Selection**
25 kHz	9.6 kbps	*37 hours*	10 days	*11 hours*	*69 hours*
	4.8 kbps	*56 hours*	100 days	*16 hours*	26 days
	2.4 kbps	*83 hours*	***21 months***	*27 hours*	68 days
12.5 kHz	9.6 kbps	*60 hours*	*73 hours*	*18 hours*	*22 hours*
	4.8 kbps	*120 hours*	29 days	*36 hours*	*200 hours*
	2.4 kbps	*210 hours*	***8 months***	*60 hours*	71 days
6.25 kHz	9.6 kbps	*100 hours*	*92 hours*	*28 hours*	*28 hours*
	4.8 kbps	*150 hours*	*130 hours*	*43 hours*	*38 hours*
	2.4 kbps	*210 hours*	*190 hours*	*60 hours*	*53 hours*

For land mobile channelizations, MES uplink data rates, and other parameters that are different from those used in this example, interpolation may be used to determine approximate values of probabilities of interference and mean times between interference events.

3 Potential interference from land mobile stations into non-GSO MSS satellites

The model of Section 3 of the annex of this recommendation performs a simulation to determine the number of land mobile stations within the MSS satellite uplink beam that can operate in the shared spectrum and still provide an average of at least 6 channels per satellite for the MSS uplinks. The average per satellite assumption is worst case, since the average over all of the visible satellites will be greater than the average per satellite, and thus provides a lower bound on the number of land mobile stations that can operate in the shared spectrum. The satellite footprint is roughly the size of the contiguous United States, 12 million km^2.

Four land mobile station average activity factors were considered, 0.01, 0.003, 0.001, and 0.0003 Erlang[1]. These correspond to averages of 432, 130, 43, and 13 minutes per month of land mobile station transmissions, respectively. Assuming a 0.4 voice activity factor, the equivalent conversation times are 1,080, 325, 108, and 33 minutes per month. Note that the averages are over the entire population of land mobile stations and over the entire month.

[1] Erlang is a measure of traffic intensity. In this context it is a measure of the land mobile station utilization.

Table A-4 shows lower bounds on the number of land mobile stations in the contiguous United States operating in 1 MHz of shared spectrum computed by the simulation program for the range of parameters examined.

Table A-5 shows the lower bounds assuming 5 MHz of shared spectrum. The lower bounds are significantly greater than 5 times those for 1 MHz of shared spectrum.

TABLE A-4

Lower Bound Number of Land Mobile Stations in 1 MHz of Shared Spectrum

		Land Mobile Station Average Activity Factor			
Land Mobile Channelization	**MES Uplink Data Rate**	**0.01 Erlang**	**0.003 Erlang**	**0.001 Erlang**	**0.0003 Erlang**
25 kHz	9.6 kbps	12,000	38,000	120,000	380,000
	4.8 kbps	17,000	55,000	170,000	550,000
	2.4 kbps	23,000	77,000	230,000	770,000
12.5 kHz	9.6 kbps	16,000	52,000	160,000	520,000
	4.8 kbps	24,000	80,000	240,000	800,000
	2.4 kbps	35,000	120,000	350,000	1.2 million
6.25 kHz	9.6 kbps	18,000	60,000	180,000	600,000
	4.8 kbps	35,000	120,000	350,000	1.2 million
	2.4 kbps	58,000	190,000	580,000	1.9 million

TABLE A-5

Lower Bound Number of Land Mobile Stations in 5 MHz of Shared Spectrum

		Land Mobile Station Average Activity Factor			
Land Mobile Channelization	**MES Uplink Data Rate**	**0.01 Erlang**	**0.003 Erlang**	**0.001 Erlang**	**0.0003 Erlang**
25 kHz	9.6 kbps	110,000	370,000	1.1 million	3.7 million
	4.8 kbps	125,000	420,000	1.3 million	4.2 million
	2.4 kbps	170,000	570,000	1.7 million	5.7 million
12.5 kHz	9.6 kbps	115,000	380,000	1.2 million	3.8 million
	4.8 kbps	190,000	630,000	1.9 million	6.3 million
	2.4 kbps	255,000	850,000	2.6 million	8.5 million
6.25 kHz	9.6 kbps	120,000	400,000	1.2 million	4.0 million
	4.8 kbps	230,000	770,000	2.3 million	7.7 million
	2.4 kbps	450,000	1.5 million	4.5 million	15 million

For parameter values not presented in the tables, interpolation may be used to determine approximate values of the lower bound numbers.

Source: Document 8D/135

ATTACHMENT 2

WORKING DOCUMENT FOR DRAFT NEW RECOMMENDATION

A METHODOLOGY FOR CALCULATING INTERFERENCE PROBABILITY FROM NON-GSO MSS MOBILE EARTH STATION TO LAND MOBILE STATION OPERATING BELOW 1 GHz

Summary

This text provides an analytic methodology for calculating interference probability from non-GSO MSS mobile earth station to land mobile station, under the circumstances as follows; a) interference from MES stations to base station of the existing LMS station with higher antenna, b) interference not only to LMS stations but also to radio-relay stations of LMS, C) using propagation model derived from ITU-R Recommendation PN.370-7.

The ITU Radiocommunication Assembly,

considering

a) that Resolution 214 (WRC-95) invited the ITU-R to study and develop Recommendations on the technical and operational issues relating to sharing between services having allocations and the non-GSO MSS below 1 GHz;

b) that the spectrum already allocated or being considered for allocation by world radio conferences for non-GSO MSS below 1 GHz, if shared with land mobile services, must provide adequate protection from harmful interference;

c) that, in some countries, there exists very high traffic of land mobile services;

d) that the distribution of MES users may be concentrated into a specific area within the footprint of one satellite, taking into consideration geographical restriction;

e) that a propagation using scattering model for VHF band is provided by ITU-R Recommendation PN.370-7;

recommends

that the methodology described in Annex 1 be used to evaluate frequency sharing between the stations in the land mobile services and the mobile earth stations in the non-GSO MSS in the same frequency band.

ANNEX 1

A Methodology for Calculating Interference Probability from Non-GSO MSS Earth Station to Land Mobile Station Operating below 1 GHz

1 Introduction

In the World Administrative Radio Conference (WARC-92) of 1992, the 148 - 149.9 MHz band was newly allocated to Non-Voice Low Speed Data Communications Services using Non-Geostationary satellite Orbit (Non-GSO MSS system), however, the introduction of Non-GSO MSS system in the newly allocated band shall be subject to the sharing of the frequency with the existing systems. WARC-92 allocated the frequency band with Radio Regulation No. 608c that Mobile Satellite Services (MSS) stations shall not cause any harmful interference to the stations of Fixed Service (FS) and Mobile Service (MS). Since WARC-92, ITU-R SG 8 WP 8D has been making extensive studies on the frequency sharing analysis between Non-GSO MSS systems and the existing systems.

This document proposes a methodology for evaluating interference probability, a) considering a interference from MES to base stations of the existing LMS station with a high antennas, b) using a propagation model derived from ITU-R Recommendation PN.370-7. Japanese Contribution 8D/134, titled "Frequency Sharing Study Between Non-GSO MSS Earth-to-Space Links and the Land Mobile Service in the 148 - 149.9 MHz" presents the examples of computation result of the interference probability using the proposed method.

2 Interference model between non-GSO MSS system and land mobile communications system

The frequency band 148 - 149.9 MHz allocated for Earth-to-space direction in the Non-GSO MSS system is used as forward and return links in the Land Mobile Communications systems. The operation of Non-GSO MSS system in the frequency band 148 - 149.9 MHz could give rise to the following four interference cases between these two systems, as shown in Fig. 1 :

(1) Interference from MES of Non-GSO MSS system to Base Station of the existing MS system.

(2) Interference from MES to LMS of the existing MS system.

(3) Interference from Gateway Earth Station of Non-GSO MSS system to Base Station.

(4) Interference from Gateway Earth Station to LMS.

Among these four interference cases, (1) and (2) are the interference paths from MES to the existing MS systems.

This document proposes the methodology for evaluating the interference probability in the interference paths (1) and (2).

For the interference paths (1) and (2), it is necessary to make assessment of the existing systems in both of the following operation modes:

(i) The existing system is in the communications mode.

(ii) The existing system is in the waiting mode.

The waiting mode described (ii) above is the case that no information is being exchanged between two stations, but the MS receivers are turned on to accommodate any call or information. When the MS system is in the waiting mode, the receiver except for the receivers with use of Tone Squelch techniques, will have squelch break during burst length $+\alpha$ (max. 450 ms $+\alpha$, for example) emitted by MES with the interference probability mentioned hereunder.

The following presents the methodology for evaluating the interference probability occurring in the interference paths (1) and (2) as shown in Fig. 1, where the existing systems are both in the communications and waiting modes.

3 Propagation loss between MES and base station of MS system

According to ITU-R Recommendation M.1039 and ITU-R Report 567, the propagation losses are given by the following equation, where h_t (m) is the height of transmission antenna, h_r (m) is the height of receiving antenna, and d (km) is the distance between the antennas:

$$L(d) = 120.02 - 20\log(ht \times hr) + 40\log d \quad (dB) \tag{1}$$

However, equation (1) can be used only when the product of (h_t x h_r) is around 10 m^2 as described in ITU-R Recommendation M.1039. In other words, equation (1) can apply only to the interference path from MES to LMS with both antenna heights around 1.5 m. In the case of the interference path from MES to Base station, it should be difficult to apply the equation (1), because the antenna height of Base station is expected to exceed 10m.

Amongst the ITU-R documents, only ITU-R Recommendation PN.370-7 describes the propagation loss in VHF band from the antennas at high altitude. This Recommendation shows the experiments results of the field strength of TV signals in VHF band at the receiving station at d km away. The results are shown for various height of antennas. From the above reasons, the propagation loss, required for obtaining the interference coordination distance between MES and Base station, is evaluated on the basis of ITU-R Recommendation PN.370-7. Fig. 2 shows the propagation loss to the propagation distance for the various antenna heights obtained from ITU-R Recommendation PN.370-7. Fig. 2 also shows the propagation loss given by equation (1) for the case of ht x hr = 1.5m x 1.5m as the reference. In the computation of propagation loss shown in Fig. 2, 10% of the time values are used, which are proposed in the ATTACHMENT 16 to the output Document 8D/84 of the last ITU-R WP 8D meeting.

4 System parameters

Fig. 3 shows the interference model from the MES to the Base station and to the LMS of the existing MS system. System parameters of Base station, LMS and MES used in the following consideration are summarized below. Suffix i indicates "Interfering system", w is "Interfered system", t is "transmitter", and r is "receiver". Also, b and m indicate "Base station" and "LMS", respectively.

(1) MES parameter (Interfering station)

[Transmission side]

Transmission Power : P_{it} (dBm)
Transmission Antenna Gain : G_{it} (dB)
MES Antenna Height : h_i (m)

(2) Base station parameter (Interfered station)

[Transmission side]

Transmission Power : P_{bwt} (dBm)
Transmission Antenna Gain : G_{bwt} (dB)
Transmission Feeder Loss : L_{bwt} (dB)
Base station Antenna Height : h_{bw} (m)

[Receiver side]

Receiving Antenna Gain : G_{bwr} (dB)
Receiving Feeder Loss : L_{bwr} (dB)
Base station Antenna Height : h_{bw} (m)
Receiver Sensitivity : C_b (dBm)
Required C/I : $(C/I)_{br}$ (dB)
Permissible Interference Level : I_b (dBm)
Squelch Sensitivity : P_{bsd} (dBm)

(3) LMS parameter (Interfered station)

[Transmission side]

Transmission Power : P_{mwt} (dBm)
Transmission Antenna Gain : G_{mwt} (dB)
LMS Antenna Height : h_{mw} (m)

[Receiver side]

Receiving Antenna Gain : G_{mwr} (dB)
LMS Antenna Height : h_{mw} (m)
Receiver Sensitivity : C_m (dBm)
Required C/I : $(C/I)_{mr}$ (dB)
Permissible Interference Level : I_m (dBm)
Squelch Sensitivity : P_{msd} (dBm)

5 Computation of the interference coordination distance when the existing MS system is in the communications mode

5.1 Interference from MES to base station (Path (1) in Fig. 3)

It is assumed that d1 is the maximum distance between Base station and LMS that the transmitted signal from LMS can be received with the necessary S/N at Base station. This d1 is equivalent to the radius of the service area of the existing MS system, namely, the circle with a radius of d1 surrounding Base station represents the service area for the MS system. Under the assumptions above and the sensitivity of Base station receiver is assumed as C_b, the following equation is obtained :

$$C_b = P_{mwt} + G_{mwt} - L(d1) + G_{bwr} - L_{bwr} \tag{2}$$

Where P_{mwt} represents LMS transmission power, G_{mwt} is LMS transmission antenna gain, L(d1) is propagation loss along the distance of d1 between Base station and LMS, G_{bwr} is Base station receiving antenna gain and L_{bwr} is Base station receiving feeder loss.

From equation (2), propagation loss between Base station and LMS is expressed by the following equation and the propagation distance, d1, can be obtained by using Fig. 2:

$$L(d1) = P_{mwt} + G_{mwt} + G_{bwr} - L_{bwr} - C_b \tag{3}$$

The required $(C/I)_{br}$ at Base station can be given by the following equation:

$$(C / I)_{br} = C_b - I_b \tag{4}$$

Where $(C/I)_{br}$ is ratio of the required desired signal power to the interference signal power at Base station, C_b is sensitivity of Base station receiver, and I_b is permissible interference power from MES.

From equation (4), the permissible interference power level is expressed by the following equation:

$$I_b = C_b - (C / I)_{br} \tag{5}$$

Assuming that more than one Non-GSO MSS systems are operated in the same band, the permissible interference power level given in equation (5) will be shared by these Non-GSO MSS systems. In the case of multiple Non-GSO MSS systems operating in the same frequency band, the following equation should substitute for equation (5):

$$I_b = C_b - (C / I)_{br} - \alpha \tag{5'}$$

where, α is the correction factor for the case of multiple operation of Non-GSO MSS systems with use of the same frequency band. If each Non-GSO MSS system could use the dedicated frequency band by using such the band segmentation method, the permissible interference power level for each system can be given by equation (5).

When Base station and MES are apart by the interference coordination distance, d_{bcor}, the interference signal power from MES would be received by Base station as the permissible interference power level, I_b. Therefore, the following equation can be obtained. These relationship is shown in Fig. 4.

$$I_b = P_{it} + G_{it} - L(d_{bcor}) + G_{bwr} - L_{bwr} - I_{so} \tag{6}$$

Where I_{so} represents the isolation in the case that Non-GSO MSS system adopts those channels interstitial between the existing system channels. Annex 1 shows the computer simulation results on the improvement of adjacent channel isolation level in the interstitial channelling.

From equations (5) and (6), when Base station and MES are apart by the interference coordination distance, d_{bcor}, the propagation loss, $L(d_{bcor})$ is expressed by the following equation:

$$\begin{aligned} L(d_{bcor}) &= P_{it} + G_{it} + G_{bwr} - L_{bwr} - I_{so} - I_b \\ &= P_{it} + G_{it} + G_{bwr} - L_{bwr} - I_{so} - C_b + (C/I)_{br} \end{aligned} \tag{7}$$

From equation (7) and Fig. 2, d_{bcor} can be obtained which represents the interference coordination distance between Base station and MES when LMS of the existing system is communicating at the edge of the service area. In other words, it is assumed that all LMSs are operating at the edge of the service area. It is obviously understood from Fig. 4 that those LMSs nearer to Base station can secure higher S/N.

5.2 Interference from MES to LMS (Path (2) in Fig. 3)

It is assumed that d2 is the maximum distance between Base station and LMS that the transmitted signal from Base station can be received with the necessary S/N at LMS. This d2 is equivalent to the maximum distance for LMS to receive the signals from Base station with the necessary S/N.

Under the assumption above and the sensitivity of LMS receiver is assumed as C_m, the following equation can be obtained :

$$C_m = P_{bwt} + G_{bwt} - L_{bwt} - L(d2) + G_{mwr} \tag{8}$$

Where P_{bwt} is Base station transmission power, G_{bwt} is Base station transmission antenna gain, L_{bwt} is Base station transmission feeder loss, L(d2) is the propagation loss in the distance d2 between Base station and LMS, and G_{mwr} is LMS receiving antenna gain.

From equation (8), the propagation loss between Base station and LMS can be expressed by the following equation:

$$L(d2) = P_{bwt} + G_{bwt} - L_{bwt} + G_{mwr} - C_m \tag{9}$$

Where $(C/I)_{mr}$ is ratio of the required desired signal power to the interference signal power at LMS, C_m is LMS receiver sensitivity and I_m is the permissible interference power, those are expressed by the following equation:

$$(C/I)_{mr} = C_m - I_m \tag{10}$$

From equation (10), the permissible interference level I_m can be expressed by the following equation:

$$I_m = C_m - (C/I)_{mr} \tag{11}$$

In the case that more than one Non-GSO MSS systems are operated in the same band, the same correction factor defined in equation (5') is required to obtain the permissible interference power level for each Non-GSO MSS system.

If LMS and MES are apart by the interference coordination distance, d_{mcor}, the interference power from MES would be received by LMS as permissible interference power, I_m, as shown in Fig. 5. This can be expressed by the following equation:

$$I_m = P_{it} + G_{it} - L(d_{mcor}) + G_{mwr} - I_{so} \tag{12}$$

From equations (11) and (12), $L(d_{mcor})$, the propagation loss of the interference coordination distance, d_{mcor}, can be expressed by the following equation:

$$\begin{aligned} L(d_{mcor}) &= P_{it} + G_{it} + G_{mwr} - I_{so} - I_m \\ &= P_{it} + G_{it} + G_{mwr} - I_{so} - C_m + (C/I)_{mr} \end{aligned} \tag{13}$$

From equation (13) and Fig. 2, d_{mcor} can be obtained which represents the interference coordination distance between LMS and MES. This coordination distance corresponds that LMS is communicating at the edge of the service area of the existing system. This assumption allows those LMS nearer to Base station enjoy higher S/N, as illustrated in Fig. 5.

6 Computation of the interference coordination distance when the existing MS system is in the waiting mode

6.1 Interference from MES to Base station (Path (1) in Fig. 3)

As illustrated in Fig. 6, it is assumed that Base station would receive the interference power equal to its squelch sensitivity when MES emits at a distance d_{bi} from Base station. In this case, the distance d_{bi} represents the interference coordination distance between MES and Base station in the waiting mode. Where P_{bsd} is Base station squelch sensitivity, the following equation can be obtained:

$$P_{bsd} = P_{it} + G_{it} - L(d_{bi}) + G_{bwr} - L_{bwr} - I_{so} \tag{14}$$

$L(d_{bi})$ is the distance between Base station and MES that makes Base station receive the interference power equal to its squelch sensitivity. From equation (14) and Fig. 2, the interference coordination distance, d_{bi}, can be obtained.

6.2 Interference from MES to LMS (Path (2) in Fig. 3)

As illustrated in Fig. 7, it is assumed that LMS would receive the interference power equal to its squelch sensitivity when MES emits at a distance d_{mi} from LMS. In this case, the distance d_{mi} represents the interference coordination distance between MES and LMS in the waiting mode. Where P_{msd} is MS squelch sensitivity, the following equation can be obtained:

$$P_{msd} = P_{it} + G_{it} - L(d_{mi}) + G_{mwr} - L_{mwr} - I_{so} \tag{15}$$

$L(d_{mi})$ is the distance between LMS and MES that makes LMS receive the interference power equal to its squelch sensitivity. From equation (15) and Fig. 2, the interference coordination distance, d_{mi}, can be obtained.

7 Probability that MES transmitters are activated

In the previous sections, the methods are presented to evaluate the interference coordination distances for two potential interference paths of between MES and Base station, and MES and LMS, when the existing systems are in the communications mode and in the waiting mode, respectively. This section proposes the method for obtaining the probability that one MES in the area of interference coordination contour is activated.

Figure 8 shows the illustrative drawing that can be used in the evaluation of the probability that one MES transmitter is activated. In Fig. 8, S shows the beam coverage of Non-GSO satellite, and S1 shows the service coverage of MSS system where MESs are assumed to be distributed uniformly. S2 shows the interference coordination contour with a radius equal interference coordination distance between MES and Base station, or MES and LMS. In Fig. 8, the Base station or LMS of the existing system would experience an unacceptable interference, if MES in the area of S2 transmits a signal under certain conditions towards satellite.

In addition to the assumption shown in Fig. 8, the followings are assumed to obtain the probability that one MES is activated. The maximum number of simultaneous operable channels for one Non-GSO satellite is assumed as m, and these m channels are always occupied by MESs to the number of N which are assumed to be uniformly distributed in the area of S1. These assumptions are considered as the worst case in the evaluation of the interference probability from Non-GSO MSS system to the existing system.

Under the assumption that MESs are uniformly distributed in the area of S1, the expected number of MESs existing in the area of S2, N(S2), is given by the following equation.

$$N(S2) = N \times {S2}/{S1} \tag{16}$$

From equation (16) and the assumption that all MESs in the area of S1 have the same probability of call originating, the probability that one MES is activated in the area of S2 is given by the following equation:

$$\begin{aligned} Pb(S2) &= N(S2) \times {1}/{N} \\ &= 1 \times {S2}/{S1} \end{aligned} \tag{17}$$

where, (1/N) represents an assumption that each channel is always occupied by one MES which is randomly selected from among N units of MESs distributed in the area of S1. From equation (17), it can be observed that the probability that one MES is activated, is independent upon the total number of MES under the assumption that all operable channels are always occupied by MESs distributed in the area of S1. In equation (17), the area of S2 can be obtained by using the interference coordination distances which are given by equations (7), (13), (14) and (15).

When the Base station or LMS of the existing MS system is in the communications mode, the probability that one MES in the area of S2 is activated, can be given by the following equations, respectively.

(1) Base station of MS system is in the communications mode:

$$P_{bc} = 1 \times \pi \times d_{bcor}{}^2 / S1 \tag{18}$$

(2) LMS of MS system is in the communications mode:

$$P_{mc} = 1 \times \pi \times d_{mcor}{}^2 / S1 \tag{19}$$

When the Base station or LMS of the existing MS system is in the waiting mode, the probability that one MES in the area of S2 is activated, can be given by the following equations, respectively.

(1) Base station of MS system is in the waiting mode:

$$P_{bw} = 1 \times \pi \times d_{bi}{}^2 / S1 \tag{20}$$

(2) LMS of MS system is in the waiting mode:

$$P_{mw} = 1 \times \pi \times d_{mi}{}^2 / S1 \tag{21}$$

8 Other parameters to be considered

For the evaluation of interference probability from MES to the existing system either in the communication mode or waiting mode, it is necessary to take the following parameters into consideration in addition to the probabilities, that one MES in the area of interference coordination contour is activated, obtained in the previous section.